INTERNATIONAL STANDARD

ISO 3611

Third edition
2023-05

Geometrical product specifications (GPS) — Dimensional measuring equipment — Design and metrological characteristics of micrometers for external measurements

Spécification géométrique des produits (GPS) — Équipement de mesurage dimensionnel — Caractéristiques de conception et caractéristiques métrologiques des micromètres d'extérieur

Reference number
ISO 3611:2023(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 290, *Dimensional and geometrical product specification and* verification, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 3611:2010), which has been technically revised.

The main changes are as follows:

— general design characteristics have been removed and reference to ISO 14978:2018 has been included;

— metrological characteristics have been clarified and modified;

— requirements for test methods have been included;

— classification system of maximum permissible errors has been added.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO 14638). It influences the chain links for measuring equipment and calibration on size and distance in the general GPS matrix (see Annex C).

The ISO GPS Matrix Model given in ISO 14638 gives an overview of the ISO GPS system of which this document is a part. The fundamental rules of ISO GPS given in ISO 8015 apply to this document and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this document, unless otherwise indicated; see ISO/TR 14253-6 for additional information on the selection of alternative decision rules.

For more detailed information on the relation of this document to other standards and the GPS matrix model, see Annex C.

Geometrical product specifications (GPS) — Dimensional measuring equipment — Design and metrological characteristics of micrometers for external measurements

1 Scope

This document provides the most important design and metrological characteristics of micrometers for external measurements:

— with analogue indication;

— with digital indication: mechanical or electronic digital display.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14253-1, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for verifying conformity or nonconformity with specifications*

ISO 14253-5, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 5: Uncertainty in verification testing of indicating measuring instruments*

ISO/TR 14253-6, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 6: Generalized decision rules for the acceptance and rejection of instruments and workpieces*

ISO 14978:2018, *Geometrical product specifications (GPS) — General concepts and requirements for GPS measuring equipment*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14978, ISO/IEC Guide 99 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
micrometer for external measurements
measuring instrument which gives the evaluation of a dimensional quantity of an external feature of a workpiece on the basis of movement of a spindle with a measuring face, moving relatively to a material measure and an anvil, with the movement generated by a screw thread

Note 1 to entry: The guiding elements of the spindle and of the anvil are connected by a frame.

Note 2 to entry: Usually, micrometers for external measurements have a thread as a material measure with the anvil, spindle and material measure arranged in a line.

3.2
measuring face contact
contact between the measuring face and an integral feature of a workpiece

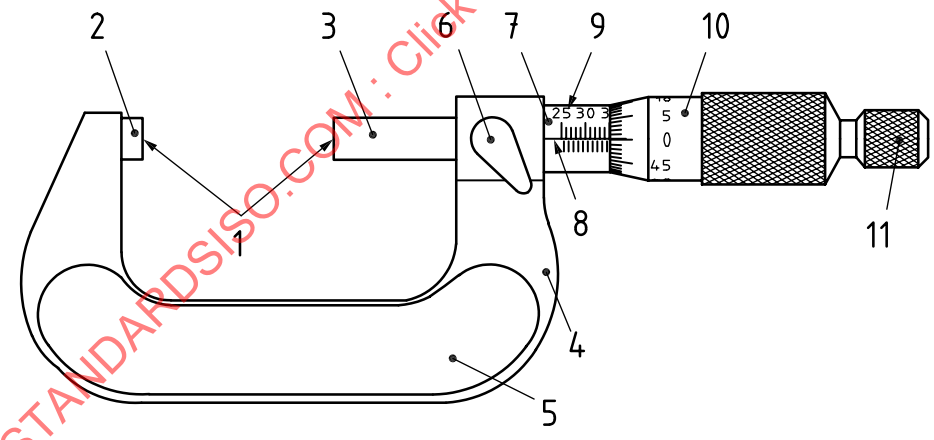
3.3
full measuring face contact
contact between the full area of the measuring face and an integral feature of a workpiece

3.4
partial measuring face contact
contact between a partial area of the measuring face and an integral feature of a workpiece

4 Design characteristics

4.1 General design and nomenclature

The design of a micrometer for external measurements shall follow the general guidelines in ISO 14978, including the common design characteristics in ISO 14978:2018, Annex C. See Figure 1 for an example of the general design.



Key

1	measuring faces	7	sleeve
2	anvil	8	fiducial line
3	measuring spindle	9	analogue indication
4	frame	10	thimble
5	thermally insulating plate	11	fast drive
6	spindle clamp		

Figure 1 — Nomenclature and general design of a micrometer for external measurements

4.2 Dimensions

The manufacturer shall state important dimensions, such as those shown in Figure 2 and Table 1. The values shown in Table 1 are typical dimensions and are not requirements of this document.

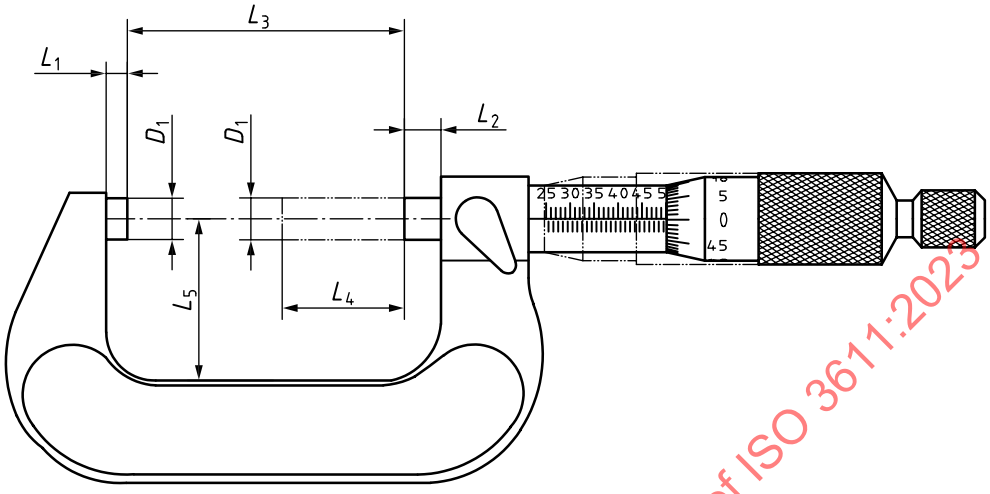


Figure 2 — Dimensions of a micrometer for external measurements

Table 1 — Dimensions of a micrometer for external measurements

Dimension	Nominal value
Anvil length, L_1	
Spindle length at maximum position, L_2	
Maximum dimension measurable, L_3	
Measuring span, L_4	25 mm[a]
Frame depth, L_5[b]	
Spindle and anvil diameter, D_1	

NOTE The dimensions D_1, L_1 and L_2 are important for the interchangeability of accessories mounted on the measuring faces.

[a] Usually, the measuring span L_4 is 25 mm. Other measuring spans are possible.

[b] Usually, the frame is shaped to permit the measurement of a cylinder whose diameter is equal to the last value of the measuring range.

4.3 Types of indicating device

4.3.1 General

Several types of indicating device are possible:

— analogue indicating devices;

— digital indicating devices with mechanical digital display;

— digital indicating devices with electronic digital display.

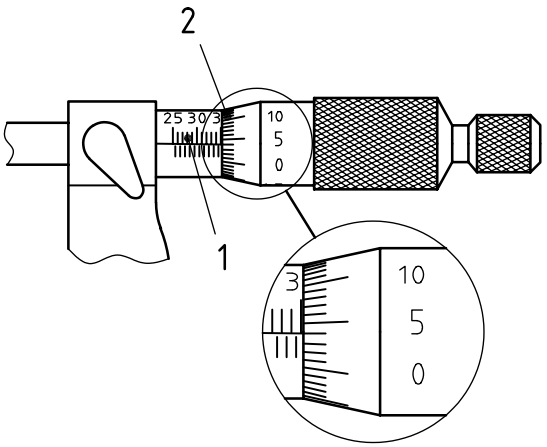
NOTE Combinations of analogue and digital indicating devices are possible.

4.3.2 Analogue indicating devices

The measuring spindle should have a pitch of 0,5 mm or 1 mm. In the case of micrometers with spindles having a pitch of 0,5 mm, the 0,5 mm graduation lines on the main scale shall be clearly distinguishable

from the 1 mm graduation lines by means of their arrangement above and below the fiducial line. See Figures 3 and 4.

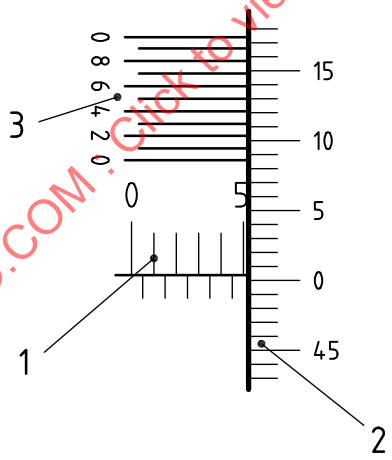
The secondary scale on the thimble should have a scale graduated with 50 (pitch 0,5 mm) or 100 (pitch 1 mm) graduation lines, each scale interval representing 0,01 mm. For graduations of 0,001 mm, a vernier scale can be added on the sleeve. See Figure 4.



Key

1 main scale
2 secondary scale

Figure 3 — Analogue indicating device with spindle pitch of 0,5 mm



Key

1 main scale
2 secondary scale
3 vernier scale

Figure 4 — Analogue indicating device with spindle pitch of 0,5 mm and vernier scale interval of 0,001 mm

4.3.3 Digital indicating devices

The mechanical or electronic digital display should have a digital step of 0,01 mm or 0,001 mm.

4.4 Frame

The rigidity of the frame shall be consistent with the measuring force. For hand-held micrometers, the frame can be insulated to prevent body heat from being transmitted.

4.5 Measuring force limiting device

Each micrometer for external measurements shall be provided with a measuring force limiting device integrated in the thimble or in the fast drive.

NOTE Typical measuring force limiting devices include ratchet and friction devices.

The measuring force generated by the measuring force limiting device should exceed the frictional force of the spindle. See 5.7.

5 Metrological characteristics

5.1 General

The metrological characteristics and associated maximum permissible error (MPE) values apply to any indications permitted for use of the micrometer for external measurements as defined by the manufacturer and when used in accordance with the manufacturer's recommendations. The MPE values cannot be smaller than the digital step but may be smaller than the scale interval. See Clause B.6 for more information on reading indications between scale marks.

5.2 Rated operating conditions

The manufacturer shall state any rated operating conditions that apply to the MPE values. All MPE values apply at a rated operating condition for temperature of 20 °C exactly, unless otherwise stated. Test values shall therefore be corrected to 20 °C to obtain the error of indication that the micrometer for external measurements would have produced had the test been performed at 20 °C. If temperature correction to 20 °C is not performed, this document allows the consequences to be included in the evaluation of the measurement uncertainty of the test values (see 6.2).

A micrometer for external measurements is a manually operated measuring instrument, and the user of the micrometer for external measurements is therefore necessarily included in the measuring system that is specified in accordance with this document. The user shall be reasonably skilled in the operation of the micrometer for external measurements.

5.3 Reference point

Each micrometer for external measurements shall be provided with user-accessible means for setting the micrometer to zero or to the reference point. For further information, see Annex B. The metrological characteristics described in this document apply when the micrometer for external measurements is properly set in accordance with the manufacturer's recommendations, and the reference point is considered fixed at the beginning of the measuring range when evaluating the metrological characteristics.

5.4 Test methods

The errors of indication shall be tested with suitable measurement standards, e.g. with gauge blocks in accordance with ISO 3650. When testing conformity to specification, sufficient testing shall be used to establish confidence in the results.

For acceptance testing, the customer is free to choose the test points; however, unless otherwise specified, the acceptance testing shall conform to the requirements in this document.

When considering test points, appropriate consideration shall be given to the design of the micrometer for external measurements and operating conditions that can indicate the presence of short-length cyclic errors.

See Annex A for guidelines on calibration and test methods.

5.5 Length measurement error, E (limited by E_{MPE})

5.5.1 General

The length measurement error, E, is the error of indication when full measuring face contact is employed to measure a measurement standard, e.g. gauge blocks, which cover the entire measuring faces of the micrometer for external measurements. This error is calculated as the signed difference between the indication of the micrometer and the reference value of the measurement standard.

The averaging of multiple indications is not permitted when calculating the length measurement error. As such, the influence of repeatability is included in the test for the length measurement error.

5.5.2 Test point selection

Once the reference point has been properly set (see 5.3), the length measurement error shall be tested by measuring measurement standards at multiple test points located across the measuring range of the micrometer. A minimum of five test points shall be taken across the measuring range. At least one test point shall be at 90 % of the measuring span or greater from the reference point. The test points shall be approximately equally distributed across the measuring range.

The test points shall also be at various angular positions of the thimble. A minimum of three angular positions approximately equally distributed shall be used. For efficiency in testing, the test points at different angular positions of the thimble may be the same test points taken across the measuring range of the micrometer for external measurements.

NOTE The length measurement error is intended to detect a combination of errors of the micrometer for external measurements, including, for example, scale errors, the rotation of the measuring spindle, the effect of the applied measuring force and the deflection of the frame.

The length measurement error, being an error of indication, applies when the micrometer is used to make a measurement, and therefore the test method involves using the micrometer to measure measurement standards such as gauge blocks across the measuring range.

5.6 Variation in length measurement error, V (limited by V_{MPE})

5.6.1 General

The variation in length measurement error, V, is the error of indication when partial measuring face contact is employed to measure a measurement standard on any position of the measuring faces of the micrometer for external measurements. The variation in length measurement error is calculated as the range of measured values when measuring one measurement standard at five positions on the measuring faces. The five default test positions are the centre of the measuring faces and four locations distributed around the periphery of the measuring faces approximately 0,4 mm from the edge.

For micrometers with a measuring range of 0 mm to 25 mm, a convenient measurement standard for testing the variation in length measurement error is a sphere. For micrometers with a measuring range that does not start at 0 mm, a convenient measurement standard is a gauge block. In this case, the gauge block shall be positioned carefully to achieve partial measuring face contact.

NOTE The variation in length measurement error includes the flatness of the measuring faces, the parallel deviation of the measuring faces and the perpendicularity deviation of each measuring face to, respectively, the anvil's axis and the measuring spindle's axis.

5.6.2 Number of tests

If the micrometer for external measurements has a rotating measuring spindle, the variation in length measurement error shall be tested twice with measurement standards of different sizes. The size of the measurement standards shall be such so that the two angular positions of the measuring spindle are approximately 180° different.

5.6.3 Testing with optical parallels

This document permits an alternative test method for the variation in length measurement error by combining the measurement of the flatness and parallelism of the measuring faces. An optical parallel, with flat and parallel faces, can be used to measure the flatness of each measuring face as well as the parallelism between the measuring faces. The arithmetic addition of the three measured values is the measured variation in length measurement error.

A set of four optical parallels shall be used for this alternative test method. The widths of the four optical parallels shall differ by approximately one-fourth of the spindle pitch. Testing shall be completed using all four optical parallels.

NOTE For the purposes of this document, the test method using optical parallels is considered equivalent to the test method described in 5.6.1 and 5.6.2.

5.7 Measuring forces

The minimum measuring force and the maximum measuring force shall be stated by the manufacturer. If not otherwise stated, the default minimum measuring force shall be 5 N and the default maximum measuring force shall be 15 N.

5.8 Specifications

5.8.1 General

For acceptance tests, specifications shall be stated by the manufacturer in accordance with this document. For reverification tests, the specifications shall be stated by the user. Table 2 provides an example of a specification sheet.

Table 2 — Example specification sheet for metrological characteristics

Characteristics	Value		
Scale interval or digital step			mm
Maximum permissible error of indication	E_{MPE}		µm
	V_{MPE}		µm
Measuring force	Maximum		N
	Minimum		N

5.8.2 Classification system

A classification system with MPE values is shown in Tables 3 to 5. The four classes provide a convenient method of stating MPE values that are intended to cover a wide variety of the micrometers for external measurements that are commonly available.

The classification system is based on a measuring span of 25 mm with a constant MPE value across the measuring range. When the measuring range of a micrometer for external measurements is different than shown for a particular class, then the applicable MPE values are based on the beginning value of the measuring range and remain constant across the measuring range.

For the MPE values in Tables 3 to 5, the decision rule that applies when demonstrating conformity or nonconformity to specification shall be simple acceptance and rejection, with the measurement capability index, C_m, being four or larger, in accordance with ISO/TR 14253-6.

Table 3 — MPE values for Class 0 micrometers with measuring range up to 50 mm

Measuring range mm	E_{MPE} µm	V_{MPE} µm
0 to 25	±0,5	0,8
25 to 50		

Table 4 — MPE values for Class 1 micrometers with measuring range up to 300 mm

Measuring range mm	E_{MPE} µm	V_{MPE} µm
0 to 25	±1	1
25 to 50		
50 to 75	±2	2
75 to 100		
100 to 125		3
125 to 150		
150 to 175	±3	4
175 to 200		
200 to 225		
225 to 250	±4	
250 to 275		
275 to 300		5

Table 5 — MPE values for Class 2 and 3 micrometers with measuring range up to 1 000 mm

Measuring range mm	Class 2		Class 3	
	E_{MPE} µm	V_{MPE} µm	E_{MPE} µm	V_{MPE} µm
0 to 25	±2	2	±4	2
25 to 50				
50 to 75	±3		±5	3
75 to 100		3		
100 to 125			±6	4
125 to 150				
150 to 175	±4		±7	5
175 to 200		4		
200 to 225			±8	6
225 to 250	±5			
250 to 275			±9	7
275 to 300		5		
300 to 325	±6		±10	8
325 to 350				
350 to 375			±11	9
375 to 400	±7	6		
400 to 425			±12	10
425 to 450				
450 to 475	±8		±13	11
475 to 500		7		
500 to 525			±14	12
525 to 550	±9			
550 to 575			±15	13
575 to 600		8		
600 to 625	±10		±16	14
625 to 650				
650 to 675			±17	15
675 to 700	±11	9		
700 to 725			±18	16
725 to 750				
750 to 775	±12		±19	17
775 to 800		10		
800 to 825			±20	18
825 to 850	±13			
850 to 875			±21	19
875 to 900		11		
900 to 925	±14		±22	20
925 to 950				
950 to 975			±23	21
975 to 1 000	±15	12		

6 Determination of conformity to specifications

6.1 General

All metrological characteristics shall conform to the specified MPE values.

6.2 Measurement uncertainty

Evaluation of measurement uncertainty shall be performed in accordance with ISO/IEC Guide 98-3. When determining conformity with specification, the measurement uncertainty associated with a test value (the test value uncertainty) shall be evaluated in accordance with ISO 14253-5. Additional guidance is available in ISO 14978:2018, Annex D.

Measurement uncertainty associated with the reference standards used in testing, as well as any uncertainty associated with temperature, shall generally be included as contributors to the measurement uncertainty. The errors of the micrometer, such as the contribution from the micrometer repeatability and resolution, are not included in the test value uncertainty.

As in 5.2, the user of the micrometer shall be skilled in the operation of the micrometer to properly determine conformity with specifications. As discussed in ISO 14253-5, when the user is sufficiently skilled, any variation in the test values associated with the skills of the user of the micrometer is generally not included as a contributor to the measurement uncertainty.

6.3 Decision rule

When demonstrating conformity or nonconformity to specifications, the decision rule accompanying the specifications shall be followed. If no decision rule is stated with the specifications, and no special agreement is made between supplier and customer, then the default rule of ISO 14253-1 shall apply.

NOTE 1 Information on the selection of an alternative decision rule can be found in ISO/TR 14253-6.

NOTE 2 For the MPE values in Tables 3 to 5, an alternative decision rule accompanies the stated MPE values.

7 Marking

The marking shall indicate at least the following data:

— the scale interval (only for analogue indication);

— the measuring range;

— the unique alphanumeric identification (i.e. serial number).

Any marking shall be easily readable and permanent; it shall be placed on the surface of the micrometer, at a place that will not impair the metrological quality of the equipment.

Annex A
(informative)

Calibration guidelines for metrological characteristics

A.1 General

The calibration of a micrometer should generally include the evaluation of the metrological characteristics of the micrometer within its measuring range.

In general, the calibration should include verification testing of all metrological characteristics across the measuring range in accordance with this document. Based on the intended use of the micrometer, a task-related calibration should be taken into consideration.

A.2 Reference or zero point

The reference or zero point of a micrometer is intended to be set by the user. The setting of the reference point is sometimes called a "calibration", but this activity is independent and separate from evaluating the performance of the micrometer as described in this document.

A.3 Testing length measurement error

As an example of testing the length measurement error, a micrometer with a measuring range of 0 mm to 25 mm can be tested using five different gauge blocks that meet the requirements described in 5.5.2. These same five gauge blocks, in combination with a single 75 mm gauge block, can be used in the calibration of a micrometer with a measuring range of 75 mm to 100 mm. In this case, the reference point is set with the 75 mm gauge block, and each of the five gauge blocks is then, in turn, wrung to the 75 mm gauge block to create the required test point. In this manner, the value of the 75 mm gauge block does not influence the test results, which is often important in the testing of larger micrometers.

A.4 Testing variation in length measurement error

As an example of testing the variation in length measurement error, a micrometer with a measuring range of 0 mm to 25 mm, with a rotating spindle that has a 1 mm pitch, can be tested using two different precision spheres that meet the requirements described in 5.6.2. Two spheres with diameters of 5 mm and 5,5 mm is an acceptable example, as the angular position of the spindle would be approximately 180° different due to the 0,5 mm difference in diameter.